

# APPLICATION OF GROWTH MODELS FOR AREA, PRODUCTION AND PRODUCTIVITY TRENDS OF SUGARCANE CROP FOR COASTAL ANDHRA REGION OF ANDHRA PRADESH

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## ABSTRACT

*The analysis of growth was used to find out the trend of a particular variable over a period of time and used for making policy decisions. The growth in the area, production and productivity of sugarcane (*Saccharum officinarum*) crop in Coastal Andhra region of Andhra Pradesh State was estimated using different linear and non-linear growth functions. The necessary secondary data were collected for a period of 40 years i.e., from 1973-74 to 2012-13. Growth rates were computed by using compound growth rates. Trend values were computed to study relative growth pattern. The future projections of area, production and productivity of sugarcane crop in Coastal Andhra region of Andhra Pradesh state up to 2019-20 AD were estimated upon the best fitted growth model. It was observed that quadratic function was the best fitted model for area and production whereas linear function for productivity. It was revealed from the results that area, production and productivity of sugarcane crop was increasing at a rate of 1.19 percent, 1.61 percent and 0.41 percent per annum, respectively.*

*Abbreviations: Adj R<sup>2</sup>–Adjusted R<sup>2</sup>, RMS- Residual Mean Square*

*KEYWORDS: Adj R<sup>2</sup>, Future projections, Sugarcane & Trend*

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## INTRODUCTION

Sugarcane is an important commercial crop in India. Sugarcane is used for making white sugar, brown sugar (Khandsari), Jaggery (Gur) and ethanol. It also provides biofuel, fiber, fertilizer and myriad of by-products with ecological sustainability. The main byproducts of sugar industry are bagasse and molasses. Molasses is raw material for alcohol and bagasse is used as raw material in the paper industry. Besides, co-generation of power using bagasse as fuel is considered feasible in most sugar mills. In India during 2013-14 sugarcane was cultivated in an area of 5.01 Million hectares with production of 350.02 million tonnes and with the productivity of 69.83 tonnes/ha. In Andhra Pradesh during 2012-13, the area under sugarcane crop was 1.56 lakh hectares and production was 120 million tonnes with productivity of 76.9 tonnes/ha. In Coastal Andhra region of Andhra Pradesh the area of sugarcane crop was 1.26 lakh hectares with production of 93 million tonnes and productivity of 73.81 tonnes/ha during 2012-13 [2].

The statistical information on crop area, production and productivity form the backbone of agricultural statistical system. Data analysis is vital since, it forms the basis for economics and policy planning by the governments. It becomes easy to formulate and initiate appropriate policy measures if the data with regard to the

trend (increase or decrease) of the production is obtained and analyzed in advance. Growth rate analysis is widely employed to study the long-term trends in various agricultural crops [4].

The objective of the present study is to study the growth rate, measure the trend and to estimate future projections by 2019-20 AD in area, production and productivity of sugarcane crop in Coastal Andhra region of Andhra Pradesh State based on ten growth models.

## MATERIALS AND METHODOLOGY

The present investigation was based on secondary data which were collected from the publications of Directorate of Economics and Statistics (DES), Ministry of Agriculture for the period of 40 years i.e., from 1973-74 to 2012-13. The study examines growth rates of area, production and yield of sugarcane in Coastal Andhra region of Andhra Pradesh by using Compound Growth Rate (CGR). The compound growth rate (CGR) is estimated by fitting an exponential function  $Y = ab^t$ , where,  $Y$  defines the time series data of area, production and yield of sugarcane, ' $t$ ' is the trend term, ' $a$ ' is the constant coefficient and ' $b$ ' is the slope coefficient. We can calculate the compound growth rate using the equation:  $CGR (\%) = (b-1) \times 100$ . The  $t$ -test was applied to test the significance of ' $b$ '.

Trend was examined by fitting ten Growth models.

**Table 1: Mathematical Equations for Ten Growth Models**

S. No	Growth Models		Mathematical Equation
1	Linear function	-	$Y_t = a + bt$
2	Logarithmic function	-	$Y_t = a + b \ln(t)$
3	Inverse function	-	$Y_t = a + b/t$
4	Quadratic function	-	$Y_t = a + bt + ct^2$
5	Cubic function	-	$Y_t = a + bt + ct^2 + dt^3$
6	Compound function	-	$Y_t = ab^t$ or $\ln Y_t = \ln a + t \ln b$
7	S-curve	-	$Y_t = \text{Exp}(a+b/t)$ or $\ln Y_t = a + b/t$
8	Growth function	-	$Y_t = \text{Exp}(a + bt)$ or $\ln Y_t = a + bt$
9	Power function	-	$Y_t = at^b$ or $\ln Y_t = \ln a + b \ln(t)$
10	Exponential fit	-	$Y_t = a \text{Exp}(bt)$ or $\ln Y_t = \ln a + (bt)$

Where,

$Y_t$  is the dependent variable i.e., area, production and productivity

$t$  is the independent variable, time in years

$a$ ,  $b$ ,  $c$  and  $d$  are the constants

The constants ' $a$ ', ' $b$ ', ' $c$ ' and ' $d$ ' are estimated by applying the Ordinary Least Square approach.

The model which showed relatively high significant Adj  $R^2$  with least residual mean square (RMS) was chosen to fit a trend equation. In best fitted model the disturbance term should satisfy the conditions of randomness. The assumption of randomness of residuals is verified by Run test.

The future projections of area, production and productivity of Sugarcane crop in Coastal Andhra region of Andhra Pradesh up to 2019-20 AD was estimated upon the best fitted growth model which were used for fitting the trend equations.

The growth rates of different crops were studied mostly through Compound growth rate by assuming the exponential functional forms ([1], [3] and [6]). Some of research workers have used linear and non-linear regression

models for measuring trends, which are currently being used by the planners or the policy makers of the country [5]; Test for randomness of the residuals by run test was also used by [5], [6]; the estimation of future projections by best fitted model was used by [6].

## RESULTS AND DISCUSSIONS

In Coastal Andhra the average area, production and productivity of sugarcane crop during the study period (1973-74 to 2012-13) were 113.24 thousand hectares, 78.6 lakh tonnes and 68.9 tonnes/ha respectively with coefficient of variation of 19.13, 23.6 and 8.43 per cent respectively.

### Growth Rates in Area, Production and Productivity of Sugarcane Crop in Coastal Andhra Region of Andhra Pradesh

Compound growth rate of sugarcane during study period (1973-74 to 2012-13) for area, production and productivity were recorded as 1.19%, 1.61% and 0.41% per annum respectively. Growth rates were found to be positive and significant at 1% level of significance and imply that production had increased at a rate of 1.61% which was due to combined effect of increase in area and productivity at a rate of 1.19% and 0.41% per annum, respectively. There was a slow process of growth in area, production and productivity of sugarcane during the study period.

### Fitting of Growth Models for Area, Production and Productivity of Sugarcane crop in Coastal Andhra

Different linear and nonlinear growth models were employed to study the trends in the area, production and productivity data of the sugarcane crop. The findings are discussed as follows.

#### Growth Models in Area

The data presented in Table. 2 for the area under the sugarcane crop revealed that among ten growth models fitted, the maximum Adj R<sup>2</sup> of 70.7% was observed in case of cubic function but run test value was found significant indicating that the residuals were not independently distributed. Hence quadratic function with Adj R<sup>2</sup> of 52.2% and RMS 230.64 which has significant runs was found to be best fitted model.

$$Y_t = 88.45 + 0.96*t + 0.009*t^2$$

(Adj R<sup>2</sup> = 52.2%)

The graph of the fitted trend for the area of sugarcane crop using the quadratic Model is shown in the Figure 1

**Table 2: Growth Models for the Area of Sugarcane in Coastal Andhra**

Model	A	b	c	d	AdjR <sup>2</sup>	RMS	Runs
Linear	85.80	1.33			0.509**	230.74	10
Logarithmic	74.39	14.08			0.304**	326.77	10
Inverse	116.58	-31.15			0.037	452.48	7
Quadratic	88.45	0.96	0.009		0.522**	230.67	9
Cubic	118.28	-7.26	0.50	-0.0081	0.707**	137.64	18
Compound	87.19	1.01			0.502**	231.28	8
Power	79.03	0.12			0.295**	453.57	7
S	4.73	-0.25			0.029	231.28	8
Growth	4.46	0.01			0.502**	313.31	9
Exponential	87.19	0.01			0.502**	231.28	8
**Significant at 1% level							
*Significant at 5% level							

### Growth Models in Production

The results shown in Table 3 reveal that Production of sugarcane in Coastal Andhra showed an increasing growth pattern during the study period. Among ten growth models fitted, the maximum Adj R<sup>2</sup> was observed in case of cubic function but it has significant run which reveals that errors are not randomly distributed. Therefore quadratic function was found to be best trend equation with significant Adj R<sup>2</sup> 60.4, least RMS (139.63) and significant runs.

$$Y_t = 57.11 + 0.68 * t + 0.01 * t^2$$

(Adj R<sup>2</sup> = 60.4%)

The graph of the fitted trend for the production of sugarcane crop using the quadratic Model is shown in the Figure 2.

**Table 3: Growth Models for the Production of Sugarcane in Coastal Andhra**

Model	a	b	c	d	AdjR <sup>2</sup>	RMS	Runs
Linear	53.24	1.24			0.597**	139.63	10
Logarithmic	42.27	13.19			0.367**	219.06	11
Inverse	82.01	-31.22			0.06	325.55	11
Quadratic	57.11	0.68	0.01		0.604**	140.62	10
Cubic	78.75	-5.28	0.37	-0.005	0.742**	89.49	20
Compound	55.10	1.01			0.573**	138.90	10
Power	48.05	0.16			0.345**	326.53	9
S	4.37	-0.37			0.047	138.90	10
Growth	4.01	0.01			0.573**	204.88	13
Exponential	55.10	0.01			0.573**	138.90	10
**Significant at 1% level							
*Significant at 5% level							

### Growth Models in Productivity

Productivity of sugarcane in Coastal Andhra region showed an increasing trend during the study period of 1973-74 to 2012-13. Among ten growth models fitted, the maximum Adj R<sup>2</sup>(31%) with least RMS (23.38) and non-significant runs (errors were distributed randomly) was found in Linear growth model. Hence trend equation is fitted by linear model.

$$Y_t = 63.15 + 0.28*t$$

(Adj R<sup>2</sup> = 31.0%)

The graph of the fitted trend for the productivity of sugarcane crop using the quadratic Model is shown in the Figure3

**Table 4: Growth Models for the Productivity of Sugarcane in Coastal Andhra**

Model	A	b	c	d	AdjR <sup>2</sup>	RMS	Runs
Linear	63.15	0.28			0.310**	23.38	14
Logarithmic	60.41	3.11			0.197**	27.19	15
Inverse	69.89	-8.39			0.037	32.61	13
Quadratic	64.75	0.05	0.005		0.35**	23.54	18
Cubic	66.42	-0.40	0.03	-0.0005	0.296**	23.86	18
Compound	63.19	1.004			0.294**	23.32	16
Power	60.80	0.04			0.184**	32.58	13
S	4.24	-0.11			0.031	23.32	16

Table 4: Contd.,							
Growth	4.14	0.004			0.294**	26.98	15
Exponential	63.19	0.004			0.294**	23.32	16
**Significant at 1% level							
*Significant at 5% level							

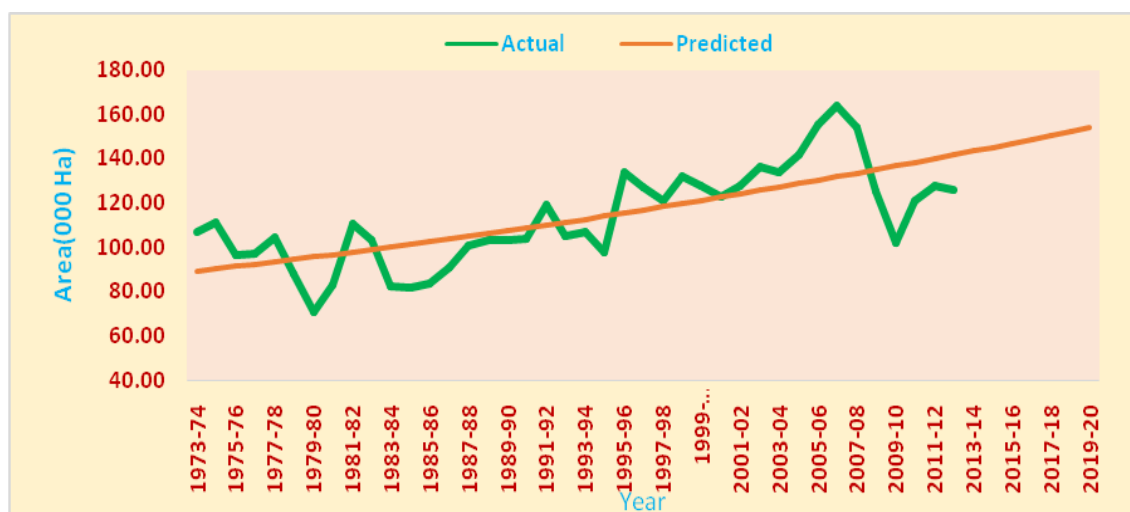
### Future Projections of Area, Production and Productivity of Sugarcane crop in Coastal Andhra Region of Andhra Pradesh up to 2019-20 AD

The future projections of area, production and productivity of sugarcane crop in Coastal Andhra region by 2019-20 AD were calculated based upon the best fitted model and the results were presented in the Table 5.

**Table 5: Projections of Area, Production and Productivity of Sugarcane in Coastal Andhra**

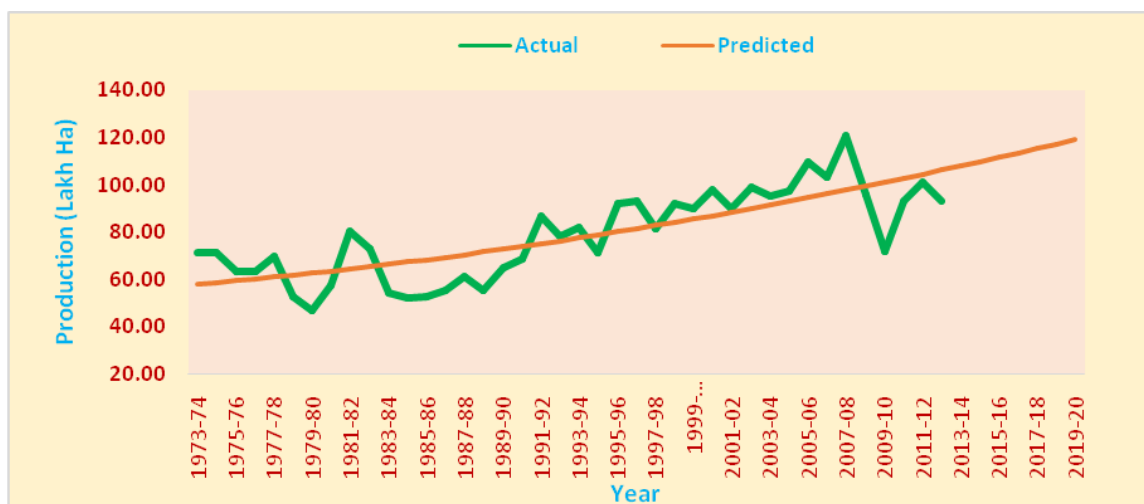
Year	Area(000 hectare)	Production (Lakh Tonnes)	Productivity (tonnes/ha)
2015-16	146.83	111.61	75.41
2016-17	148.59	113.47	75.69
2017-18	150.38	115.36	75.98
2018-19	152.18	117.27	76.26
2019-20	154.01	119.22	76.55

Area under sugarcane in Coastal Andhra was projected by using quadratic function which was found to be best for this purpose as it has high significant Adj  $R^2$  with least residual mean square and also fulfilled the assumption of randomness of residuals. The area under sugarcane projected by quadratic function by 2019-20 AD would be 154.01 thousand hectare which is in increasing trend depicted in Figure 1.



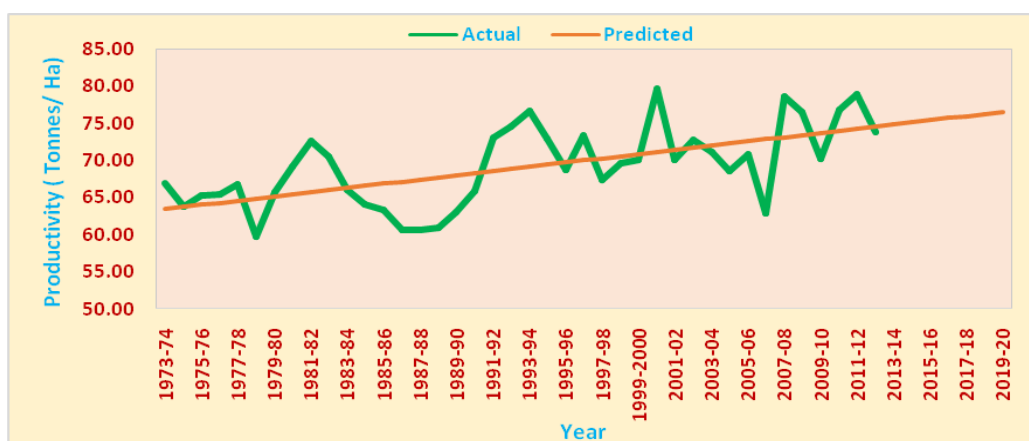
**Figure 1: Trends of Sugarcane Area in Coastal Andhra & Projections by 2019-20 AD**

Regarding the production of sugarcane, quadratic function was found to be the best model for future projections by 2019-20 AD as it has the significant Adj  $R^2$  with the assumption of randomness of residuals satisfied. The projected production would be increasing to 119.22 lakh tonnes by 2019-20 AD shown in Figure 2.



**Figure 2: Trends of Sugarcane Production in Coastal Andhra and Projections by 2019-20 AD**

Regarding the productivity of sugarcane, also linear function was found to be the best model for future projections by 2019-20 AD as it has the high significant  $\text{AdjR}^2$  with least residual mean square and also satisfied the assumption of randomness of residuals. The projected productivity would be increasing to 76.55 tonnes/ha by 2019-20 AD shown in Figure.3.



**Figure 3: Trends of Sugarcane Productivity in Coastal Andhra and Projections by 2019-20 AD**

Similar studies [6] revealed that the trends in area, production and productivity of rice crop for 40 years (1969-2009) in Andhra Pradesh and found logarithmic model in area and linear model in production and productivity were best fitted models. Those best fitted models were used for future projections by 2014 AD.

## CONCLUSIONS

The trend and growth rate of Sugarcane area, production and productivity for the period 1973-74 to 2012-13 were analysed and forecasted to the year 2019-20 in Coastal Andhra region of Andhra Pradesh. Average area, production and productivity under sugarcane in Coastal Andhra region of Andhra Pradesh during the study period were 113.25 thousand hectares, 78.67 lakh tonnes and 68.99 tonnes/ha respectively. Among the area, production and productivity, the production exhibited higher growth rates due to increased trend in growth rate of area and productivity. Results revealed that the cane production will be increased to 119.22 lakh tonnes with a CGR of 1.61% from about 154.01 thousand hectares of land with a productivity of 76.55 tonnes/ha by 2019-20.

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